ONTARIO WATER RESOURCES COMMISSION

Water quality problems in Caledonia water supply.

1965

WATER QUALITY PROBLEMS
IN
CALEDONIA WATER SUPPLY

DIVISION OF RESEARCH

ONTARIO WATER RESOURCES COMMISSION

1965

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REPORT

Ontario Water Resources Commission

Municipality Town of Caledonia Date of Inspection October 26, 1965

Re: WATER QUALITY PROBLEMS IN CALEDONIA WATER SUPPLY

Field Inspection by A. Oda and G. J. Richards Report by A. Oda

INTRODUCTION

The Town of Caledonia is located in a section of Ontario where deposits of gypsum and limestone are found in great abundance. Its water supply is obtained from shallow wells that are drilled into the bedrock formation consisting of gypsum and limestone. As a result of this, the quality of this water is adversely affected and is found to be unsatisfactory for domestic and industrial uses due to the presence of excessive hardness and unusually high mineral content.

Many of the problems experienced in the water system at Caledonia are found to be similar to those encountered at other well supplies located in this area. Perhaps, some of the more serious problems are caused by the presence of hydrogen sulphide and excessive iron in the water. Hydrogen sulphide imparts an objectionable odour to water and may also enhance its corrosive properties. High iron content creates unsightly stains on laundry and plumbing fixtures. In addition, it may cause adverse taste and odour conditions in the distribution system.

In the past, complaints of discolourations and the presence of objectionable odours in the water supply have been reported frequently by the residents of Caledonia. However, early in the fall of 1965, these conditions became critical and therefore an investigation was undertaken at the request of the municipality.

INVESTIGATION

This investigation was carried out at Caledonia on October 26 1965. Several persons including the representatives of the municipality and the local Public Utilities Commission were interviewed to ascertain the nature of the problem and to determine the locations of the trouble spots within the distribution system.

Samples of water were collected from municipal wells and from some of the points in the distribution system where poor quality water had been reported. At the sampling sites, on-the-spot tests involving the analyses of carbon dioxide, hydrogen sulphide and aggressiveness of water were performed. The results of the field tests and other pertinent data collected during this investigation can be found in the APPENDIX.

INTERVIEWS

Ten residents were interviewed during this investigation. They were asked to describe the tastes and odours that they had noticed in the water coming from the taps in their homes. Most persons described them as foul, musty, stale and septic, almost reminiscent of sewage. Two persons, who lived in the outlying areas of the town stated that they have often found very intense odours coming from their hot water taps.

Some persons complained about the frequent occurrences of discoloured water coming from the taps and appearances of unsightly stains on plumbing fixtures, especially on white enamelled surfaces. One householder stated that he has noticed that the water from his hot water tap was frequently black when it was first turned

on and then it changed into a rusty brown colour. He has found that the water from the cold water tap was often discoloured but not as intense as in the hot water.

Another common complaint was the fact that this water has a tendency to impart unpalatable discolourations and unusual tastes to hot beverages such as tea and coffee.

Mr. K. H. Baird, Manager of Caledonia Public Utilities Commission was also interviewed. He mentioned that the application of chlorine was temporarily discontinued about a month prior to this investigation. He stated that this action was taken because he had received several complaints of adverse tastes and odours which he felt, were intensified by chlorination.

GENERAL OBSERVATIONS

From these interviews, it would appear that there have been sporadic outbreaks of bad taste and odour conditions developing in the town water supply and most of the difficulties were confined to outlying areas where there have been very low flows in the distribution system. However, a few weeks prior to this investigation, complaints of unusual tastes and odours were reported from the consumers living in the central part of the town. This is an area where very few complaints concerning water quality are heard.

During the investigation, one of the worst conditions of water quality was noticed at the home of Mr. and Mrs. A. Hendry on Ross Street. Characteristic odours of hydrogen sulphide were quite noticeable in the samples from both hot and cold water taps

although they were more intense in the hot water. The odour in the sample of cold water seemed to be somewhat of a different character—a mixture of a musty odour with a tinge of "rotten eggs" smell.

It is also interesting to note that this was the only place in the municipality where hydrogen sulphide could be measured quantitatively. On-the-spot tests indicated that there was slightly less than 0.1 ppm of hydrogen sulphide present in the cold water and about 0.4 ppm in the hot water.

When the cold tap was first turned on, the water was highly coloured with very fine particles of rust, and this began to clear up within a few minutes. However, this was not the case with the water from the hot water tap. Even after running for more than five minutes, the water continued to be discoloured with a considerable amount of haziness.

The cold water had an unusual taste which could be best described as metallic with a salty flavour.

Some tell-tale odours of hydrogen sulphide were noticed in the samples of water obtained from Wells No. 1 & 2 but they could not be detected by means of any chemical tests.

At the municipal office, located at 74 Caithness Street, there were no detectable odours in the cold water but some distinct sulphurous smells were noticed in the water from the hot water tap. Large stains were found on the white enamelled surfaces of the wash basin and the bathtub in the washroom of this building. Stains appeared to be more pronounced in the areas beneath the hot water taps.

A severe case of "red" water condition in the distribution system was noticed at a fire hydrant located near the east end of Caithness Street. A homeowner whose property is situated in this area stated that he has been plagued with dirty water coming through the taps in his house.

Bacteriological examinations of the samples collected at this hydrant revealed the presence of some iron bacteria identified as Gallionella and sulphate-reducing organisms. The odours given off could be described as musty but no characteristic odour of hydrogen sulphide was detected.

DISCUSSION OF RESULTS

Water Quality

A review of the chemical data compiled in Table 3 indicated that the water derived from municipal wells is very highly mineralized and extremely "hard". Its dissolved solids content is in the range of 1400 to 2200 ppm and the total hardness from 1000 to 1400 ppm. Since this water is drawn from an aquifer or a water-bearing formation imbedded in strata of limestone and gypsum, it contains unusually large amounts of calcium and sulphates. Chemical analyses show that the concentrations of calcium and sulphates in the Caledonia water supply are approximately in the range of 200 to 400 ppm and 600 to 1100 ppm respectively.

Calcium, in high concentrations in any water supply, is considered to be undesirable because it causes scaling and sludge deposits on the heating surfaces of boilers, pipes and cooking utensils. Compounds of calcium and magnesium impart hardness to

water and this has a detrimental effect upon the cleansing action of soaps and certain detergents.

The presence of sulphates in drinking water has a pronounced laxative effect on persons who are not accustomed to them. Therefore, public health authorities have recommended that sulphates should not exceed 250 ppm except where a more suitable supply is not available. However, there are a number of public water supplies with sulphate content well above this limit and these are being constantly used without any adverse effects.

Sulphates in water supplies are an important source of nutrients for sulphate-reducing bacteria. If a distribution system becomes infested with these organisms, under proper conditions, they can thrive and produce hydrogen sulphide which can lead to serious problems of corrosion and adverse taste and odour conditions. This will be discussed later.

Corrosion Problems

A review of the analytical data in Table 3 shows that, with the exception of one sample collected on March 12, 1963, iron content in the water derived from the municipal wells is very much below the acceptable limit of 0.3 ppm. However, it is obvious from the iron analysis data presented in Table 2 that there was a considerable amount of iron being picked up in the distribution system. Excessively high concentrations of iron were found in samples collected from the hot water tanks, those taken from cold water taps in a home on Ross Street and the "dead-end" hydrant on Caithness Street.

At first glance, these data suggested that this water was very unstable and possessed corrosive properties. However, according to the calculation of Langelier's Saturation Index, it has scale-forming tendencies. (see Table 2)

Langelier's Saturation Index

In order to determine the degree of corrosiveness in any sample of water, Langelier's Saturation Index is calculated from water analysis data. This saturation index is simply a method to calculate mathematically whether or not a particular sample of water possesses any corrosive or scale-forming properties. It is expressed as $pH-pH_s$; the difference between the actual pH of the water (measured at the time of sampling) and the calculated pH saturation. The latter designated as pH_s is defined as the pH value at which the particular water would be stable with respect to calcium carbonate. pH_s can be calculated very readily if water analysis data pertaining to total dissolved solids, calcium hardness, total alkalinity and temperature were available. An interpretation of the saturation index can be found in Table 2.

Other Influential Factors

Corrosive properties of water can be enhanced by the presence of carbon dioxide and hydrogen sulphide. Field tests indicated that there were small amounts of free carbon dioxide present in the samples collected at the wells and also in the cold water tap in the Hendry home on Ross Street. (see Table 1)

Hydrogen sulphide was found to be present in the samples collected at the wellhead but in much greater amounts on Ross Street.

Carbon dioxide greatly enhances the dissolving power of water and makes it very active in corroding metals on pipes. However, carbon dioxide, in small quantities, is considered to be desirable in highly mineralized water such as in the Caledonia water supply, because it prevents the formation of heavy calcium carbonate deposits which may lead to the clogging of pipes and scaling problems.

HYDROGEN SULPHIDE

Hydrogen sulphide (H_2S) is a gaseous substance having a characteristic odour of "rotten eggs". Its presence in any potable water supply is undesirable because it creates obnoxious taste and odour problems and it may also enhance the corrosive properties of water.

In addition to causing taste and odour problems in water supplies, hydrogen sulphide has a tendency to attack metallic iron in watermains and pipes to form iron sulphides or to combine with water to form corrosive acids which may react with the metal.

For the production of hydrogen sulphide in any water supply, these three conditions are necessary:

a) presence of sulphate-reducing bacteria
b) availability of sulphates, sulphur or organic compounds containing sulphur in sufficient quantities
c) low concentration of dissolved oxygen content (This is referred to as an "anaerobic" condition).

The presence of heat tends to accelerate the metabolic activity of sulphate-reducing organisms and therefore a greater production of hydrogen sulphide can be expected.

PRESENCE OF HYDROGEN SULPHIDE IN DOMESTIC HOT WATER SYSTEM

Some difficulties with hydrogen sulphide are often encountered in domestic hot water tanks in some communities where the water supplies have a high sulphate content. Hydrogen sulphide can find its way into these tanks in one of two ways: either as a gas dissolved in water which, upon heating, is released; or it may be produced within the tank itself by means of bacterial activity.

If any sulphate-reducing organisms are able to gain an entry into the hot water tank and the three conditions as indicated above are satisfied, they will establish colonies very rapidly under the influence of higher temperatures and make their presence known.

In the Caledonia water supply, the conditions are ideal for the prolific growths of these organisms. The water has an unusually high sulphate content and the results of the field analyses in Table 1 show a very low dissolved oxygen content in the system. Because of this, the odours of hydrogen sulphide were found to be more pronounced in the samples taken from the hot water taps.

SIGNIFICANCE OF IRON AND SULPHATE-REDUCING ORGANISMS

Presence of these organisms in any water supply is undesirable because it can create many difficulties in the distribution system such as (1) fouling of the water supply, (2) clogging of waterpipes, (3) corrosion, and (4) severe taste and odour conditions. They are generally referred to as nuisance organisms.

Iron bacteria are micro-organisms capable of utilizing dissolved compounds containing iron. Concentrations of iron as low as 0.1 ppm are sufficient to support the growths of these organisms. They secrete iron and deposit ferric hydroxide (rust). They are also capable of corroding metallic iron and producing precipitates which can discolour water. These organisms and their secretions eventually decompose in the watermains and may create objectionable tastes and odours in the water supply.

Sulphate-reducing bacteria are another class of organisms that are capable of utilizing sulphates and sulphur compounds and converting them into obnoxious hydrogen sulphide.

Samples for bacterial analyses were collected at two locations only; from a home on Ross Street and the hydrant on Caithness Street. It is interesting to note that only the sample from the latter location indicated the presence of both species of organisms.

REMEDIAL MEASURES

The Town of Caledonia has a very difficult water quality problem simply because the water available for the municipal supply is very highly mineralized. However, it is believed that some of the troubles encountered in this water supply prior to this investigation could be attributed to improper chlorination practices. In order to remedy this situation, it is necessary to remove hydrogen sulphide at the wellhead and to eliminate conditions in the distribution system that might encourage the growths of nuisance organisms. This can be done very simply by proper chlorination of the entire water system on a continuous basis. A regular programme of flushing hydrants at the "dead-end" of the distribution system may be helpful in eliminating some of the problems occurring in the outlying areas.

In order to disinfect the watermains, it may be advisable to apply a much higher dosage of chlorine for a period of at least 48 hours and at the same time, the hydrants should be flushed so that the chlorinated water will penetrate quickly throughout the entire system. It is suggested that during this period of disinfection, the dosage of chlorine be increased sufficiently to give a residual of at least 1.0 ppm in the water leaving the pumphouse. Periodic checks should be made at various points in town to insure that the chlorine has reached the extremities of the system.

When this programme of disinfection has been carried out in a proper manner, the dosage of chlorine can be reduced to maintain a residual of at least 0.5 ppm in the water leaving the pumphouse.

It is advisable to maintain this chlorination on a continuous basis. In order to insure that proper mixing of chlorine and well water has taken place, it is suggested that the chlorine tests be carried out daily on the samples of water taken in the office of the P.U.C. Manager.

Because some rust, organic matter and other debris have a tendency to accumulate in areas of low flows at the dead ends of the system, undesirable tastes, odours and colour may sometimes develop in the water. Therefore, it is suggested that a programme of inspection and flushing of hydrants should be carried out at frequent intervals. The hydrant should be flushed by turning the valve wide open and allowing the water to run until clear. If suitable equipment is available, compressed air can be forced into the watermains to increase velocity and agitation. This practice will help to scour and remove much of the accumulation of debris. It may be advisable to carry out this programme at night during the periods of low water consumption.

SUMMARY AND CONCLUSIONS

An investigation was undertaken to determine the causes of adverse taste and odour problems which had developed in Caledonia's water supply during the latter part of 1965. This work was carried out on October 26, 1965 and it consisted of interviews with the local residents and collection of pertinent data from the trouble spots within the town water system.

These were some of the facts and conclusions that were obtained during this investigation:

(1) It was learned that complaints of poor water quality had been received on numerous occasions from consumers living in the outlying areas of the town. However, problems of bad tastes became more widespread a few weeks prior to the investigation.

(2) The application of chlorine was discontinued during the week of September 23, 1965. It is believed that this action may have had some definite significance on the occurrence of bad tastes in the water supply during the subsequent weeks.

(3) Although bacteriological analyses revealed the presence of nuisance organisms in a sample collected from one location only, it is believed that there were some infestations in many areas of the distribution system.

(4) Hydrogen sulphide was found in samples obtained from the municipal wells and the Henry home on Ross Street. At the latter location, it was present in concentrations that could be measured by means of the field tests.

(5) Presence of "rotten eggs" odours in the hot water indicated that some of the hot water tanks were infested with sulphate-reducing organisms.

(6) Musty odours were noted in the sample obtained from a hydrant on Caithness Street. This resulted from the activity of iron bacteria.

(7) Langelier's Saturation Index calculated from chemical data indicates that this water tends to possess inherent scale-forming properties. Therefore, it is believed that corrosion and discolouration in the water resulted from biological activity of nuisance organisms.

RECOMMENDATIONS

Present chlorination practices in the water supply at Caledonia should be reviewed at the earliest opportunity.

The entire distribution system should be flushed thoroughly and disinfected in accordance with the procedures outlined under REMEDIAL MEASURES. After this has been carried out, it is recommended that the water supply be chlorinated on a continuous basis and that chlorine dosage be increased sufficiently to maintain a minimum residual of 0.5 ppm (after 15 minutes) in the water being pumped into the distribution system. The application of higher chlorine dosages has many advantages, namely; it prolongs the period of disinfection; it prevents the reduction of sulphates to sulphides when the water remains in dead ends of the system; and it prevents the growth of nuisance organisms.

If these prescribed methods do not improve the water quality, then it is necessary to seek other methods of treatment.

Prepared by:

A. Oda

A. Oda, P. Eng.,
Technical Advisory
Services Branch.

A P P E N D I X

Table 1 - Summary of Field Analyses

Table 2 - Analytical Data for Langelier's Index

Table 3 - Chemical Composition of Well Water

Water Analysis Report

TABLE 1

SUMMARY OF FIELD ANALYSES

SAMPLES COLLECTED FROM CALEDONIA WATER SUPPLY

(October 26, 1965)

Sampling Locations	Temperatures °C	°F	Alkalinity field	lab	pH field	lab	Free CO_2 field	calculated	Dissolved Oxygen	Hydrogen Sulphide
Well No. 1	12.8	55.0	246	251	7.15	7.2	28	35.2	0.4	odours
Well No. 2	13.5	56.3	246	245	7.10	7.2	32	37.9	0.7	odours
74 Caithness St (cold)	12.8	55.8	240	244	7.30	7.1	-	24.	0.4	nil
(hot)	45.0	113.0	238	226	6.85	7.1	-	-	-	odours*
150 Renfrew St	-	-	-	244	-	7.2	-	-	-	-
124 Ross St (cold)	13.2	55.8	258	247	7.30	7.2	28.5	25.8	1.0	<0.1
(hot)	51.8	125.0	234	226	6.95	7.1	-	-	-	0.4
Caithness St (hydrant at east end)	-	-	-	160	-	7.0	-	32.0	-	nil

* Sulphurous odours

Note: All analyses except pH and temperatures are reported in parts per million (ppm)

TABLE 2

ANALYTICAL DATA FOR THE CALCULATION OF LANGELIER'S INDEX

(Samples Collected on October 26, 1965)

Sampling Locations	Temperature °F	Alkalinity as $CaCO_3$	pH	Total Diss. Solids	Calcium Hardness	pH_s	$pH-pH_s$	Iron as Fe
Well No. 1	55.0	246	7.15	1474	1120	6.76	+0.39	0.41
Well No. 2	56.3	246	7.10	1392	1030	6.76	+0.34	0.18
74 Caithness St (cold)	55.8	240	7.30	1540	1100	6.77	+0.53	0.14
(hot)	113.0	238	6.85	1500	1100	6.13	+0.72	1.02
150 Renfrew St	55.0**	244*	7.2 *	1484	1120	6.75	+0.45	0.11
124 Ross St (cold)	55.8	258	7.30	1480	1110	6.75	+0.55	5.85
(hot)	125.0	234	6.95	1500**	1090	6.03	+0.92	4.60
Caithness St (hydrant at east end)	55.0**	160*	7.0 *	1500**	980	6.00	+1.00	30.2

*Laboratory analyses
**Assumed values

Interpretation of Langelier's Saturation Index

Saturation Index = $pH-pH_s$

If the index is 0, water is in chemical balance and therefore it is stable.
If the index is positive, water may have scale-forming tendencies.
If the index is negative, water may have corrosive tendencies.

TABLE 3

CHEMICAL COMPOSITION OF WATER FROM MUNICIPAL WELLS

TOWN OF CALEDONIA

Date & Well No.		Hardness as $CaCO_3$	Alkalinity as $CaCO_3$	Iron as Fe	Chloride as Cl	Fluoride as F	pH	Calcium as Ca	Sulphates as SO_4	Dissolved Solids
Aug 10 1961	1	1320	254	0.08	18	0.5	7.4	-	630	-
Dec 13 1961	1	1370	246	0.33	18	0.5	7.6	-	1100	-
Aug 24 1962	1	1330	260	0.16	22	0.4	7.9	218	-	2020
" " "	2	990	240	0.16	27	0.6	7.4	202	-	1534
Mar 12 1963	1	1348	264	2.00	29	0.3	7.4	-	1087	-
" " "	2	1044	262	0.56	37	0.3	7.5	-	695	-
Dec 17 1963	*	1260	250	0.23	29	-	7.2	-	1080	-
July 29 1964	**	1470	262	1.00	16	0.3	7.2	-	1135	2188
Oct 26 1965	1	1270	251	0.41	24	-	7.2	448	980	1474
" " "	2	1166	245	0.18	27	-	7.2	412	875	1392

* a composite sample from 3 wells

** new wells

Note: All analyses except pH are reported in ppm.
These data were obtained from previous OWRC inspection reports.

ONTARIO WATER RESOURCES COMMISSION
CHEMICAL LABORATORIES

WATER ANALYSIS

All analyses except pH reported in p.p.m. unless otherwise indicated

1 p.p.m. = 1 mgm. / litre = 1 lb./100,000 Imp. Gals.

Municipality: Caledonia Report to: A. Oda *

c.c. Chem. Lab.-*
G. R. Trewin
General Manager-*

Source: Municipal Water Supply

Date Sampled: Oct. 26/65 by: G.J. Richards

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Lab. No.	Hardness as $CaCO_3$	Alkalinity as $CaCO_3$	Iron as Fe	Chloride as Cl	pH at Lab.	Fluoride as F	Sulphate as SO_4	Calcium as Ca	Dissolved Solids	Free Ammonia as N	Total Kjeldahl as N
W 6509	1270	251	0.41	24	7.2		980	448	1474	0.10	0.13
W 6510	1166	245	0.18	27	7.2		875	412	1392	0.10	0.13
W 6511	1262	244	0.14	25	7.1		970	440	1540	0.10	0.13
W 6512	1242	226	1.02	24	7.1		950	440	1500	0.10	0.13
W 6513	1280	244	0.11	24	7.2		966	448	1484	0.10	0.13
W 6514	1270	247	5.85	24	7.2		830	444	1480	0.10	0.13
W 6515	1240	226	4.6	25	7.1		982	436	-	0.10	0.13
W 6516	1160	160	30.2	25	7.0		836	392	-	tr	0.13

W 6509	65-135.	Well #1.
W 6510	65-136.	Well #2.
W 6511	65-137.	74 Caithness St. - cold water tap.
W 6512	65-138.	74 Caithness St. - hot water tap.
W 6513	65-139.	150 Renfrew St.
W 6514	65-140.	124 Ross St. - cold water tap.
W 6515	65-141.	124 Ross St. - hot water tap.
W 6516	65-142.	Caithness St. - hydrant.

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